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ABSTRACT

This paper presents the results of a study concerning the use of text in support of firsthand scientific inquiry instruction in the early elementary grades. A partial transcript of two teaching sessions in which an expert classroom teacher incorporated text into her inquiry instruction is investigated. The knowledge gained from these sessions helped inform the development of a new text genre modeled on a scientist's notebook. Unlike traditional texts that simply present a body of information, the notebook format models the use of scientific reasoning for children. Sections include: (1) "The Interplay of Firsthand and Text-Based Investigations in Science Education"; (2) "What Is Known about Text in Science?"; (3) "The Professional Development Context Supporting This Program of Research"; (4) "Descriptive Research on Secondhand Investigations"; (5) "Designing Text To Support Guided Inquiry Teaching"; (6) "Experimental Research Comparing the Innovative Text with Traditional Text"; (7) "Results and Discussion"; and (8) "Observational Research with the Innovative Text." (CCM)

CIERA REPORT

The Interplay of Firsthand and Text-Based Investigations in Science Education

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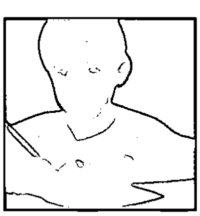

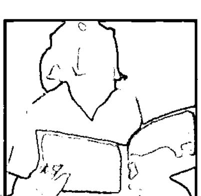

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Center for the Improvement of Early Reading Achievement

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CIERA Inquiry 2: Home and School
What is the role of text in the science instruction of young children? What are the opportunities in guided inquiry science instruction to advance young children's literacy learning?

In this paper, Palincsar and Magnusson present results of their studies of the use of text in support of firsthand scientific inquiry instruction in the early elementary grades.

Palincsar and Magnusson present a partial transcript of two teaching sessions in which an expert classroom teachers incorporated text into her inquiry instruction. The knowledge the researchers gained from these sessions helped inform the next phase of their research program—the development of a new text genre modeled on a scientist's notebook. Unlike traditional texts that simply present a body of information, the notebook format models the use of scientific reasoning for the children. The authors also hoped that this format would help children learn how to read informational texts more critically.

Palincsar and Magnusson compared the classroom use of the innovative notebook texts to the use of more traditional expository texts on the same topic. A notebook and a traditional text were constructed for each of two subtopics within the general topic of light: reflection and refraction. Students were assessed on their knowledge of these topics before and after their exposure to the texts. The authors found that the notebook genre produced significantly higher results.

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The Interplay of Firsthand and Text-Based Investigations in Science Education

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> "It's pretty cool because we get to share our thinking with the class and we get to also share Lesley's thinking with the class."
>
> "I like to listen to what other scientists do, like Lesley Park. Especially when she started getting more exact."

These quotes are taken from the remarks of two fourth graders who have been engaged in investigations of light. They are commenting on their experiences using notebook entries authored by a fictitious scientist, Lesley Park, who is documenting her own investigations of light. In this manuscript, we consider the nature and role of text designed to advance young children's thinking as they engage in scientific inquiry.

Inquiry is a complex form of thinking that has been developed over thousands of years. It is a cultural legacy that previous generations have imparted to us to employ and revise. From a sociocultural perspective, it is a "cultural tool" (Wertsch, 1998) of a psychological nature, an approach to reasoning that others have found useful. This is not, however, the perspective from which inquiry is generally approached in the worlds of teachers and students. Inquiry is often equated with discovery or framed in a manner that suggests that it is synonymous with activity-based, hands-on engagement in investigative activity. The notion that inquiry is discovery is problematic when one considers the impossibility that children will come to meaningful understandings of the nature of scientific thinking simply through the process of interacting with materials and phenomena (see also Brown & Campione, 1994). Furthermore, the notion that inquiry must be exclusively activity-based is problematic because, in fact, much of what we know about scientific reasoning has been acquired through the thinking and experiences of others—that is, through learning in a secondhand way. Frequently, although not exclusively, this secondhand learning can be facilitated with the use of text.

Text has generally suffered neglect on the part of the science education community while receiving more attention from the reading and literacy community. Although reading researchers have undertaken vigorous programs of research regarding certain issues related to science text (e.g., students' learning from refutational text), this research has not typically been situated in the context of science curriculum and pedagogy. Hence, the text used is seldom studied in the context of everyday classroom use, the dependent measures seldom reflect the goals that are represented in the science standards documents, and there is little attention given to the integration of text with other modes of experiencing and learning science.

In addition to the argument framed above regarding the significant role that secondhand investigations with text can play in advancing science learning, there are at least three other compelling reasons to argue for research related to the study of text in elementary science instruction. First, national standards documents include the recommendation that students "learn how to access scientific information from books, periodicals, videos... and evaluate and interpret the information they have acquired from these resources" (National Research Council, 1996, p. 45). Furthermore, these reform documents urge that teachers assume an inquiry approach as they guide students in "acquiring and interpreting information" from text (p. 3). These recommendations place challenging demands on classroom teachers, particularly elementary teachers who are unaccustomed to using informational text (Fisher & Hiebert, 1990), much less using such text to promote inquiry. Although the reform documents hint at the use of text as a default experience when students are unable to experience phenomena in a firsthand fashion, we are, in fact, interested in ways that secondhand experiences with text can: (a) prepare students for firsthand experiences in very powerful ways, (b) effectively extend firsthand experiences, and (c) provide a common inquiry that advances students' conceptual understanding in significant ways.

Second, the reform documents suggest that one mark of scientific literacy is the ability to critically read informational text. As the research of Norris and Phillips (1994) demonstrates, even students who had experienced advanced level science courses (i.e., high school seniors who had taken four science courses) struggled to be critical of popular science reports and failed to be discriminating regarding truth statements, ascribing higher truth values to statements than were warranted by the information provided. Clearly, the competence to understand and critically analyze text will not be developed without careful and systematic attention to cultivating the skills and dispositions of teachers and students to approach science text in a critical fashion throughout the grades.

A third motivation for the study of text in science instruction is particular to the elementary grades. In this information age, it is well recognized that the attainment of informational literacy is central to achievement, or even survival, in securing a place in advanced schooling, in one's job, and in one's community. Despite this fact, American schools have failed to develop effective and enduring informational reading and writing skills for many students, particularly those from traditionally disenfranchised social groups (Applebee, Langer, Mullis, Latham, & Gentile, 1994). Chall, Jacobs, and Baldwin (1990) have argued that the well-documented "fourth-grade slump" can be explained in terms of the difficulties that students experience with informational text. One likely explanation for this difficulty is the paucity of opportunities students have had to learn from and about informational text (Duke, in press; Hiebert & Fisher, 1990; Pappas, 1991).

In this paper we describe the design, conduct, and outcomes of a program of research that is focused on students' and teachers' use of text in the context of guided inquiry science instruction. We begin with a discussion of related research and continue with a brief description of the professional development context in which our research has been conducted. This is followed by a description of an observational study in which we examined the practices of an expert elementary classroom teacher who incorporated text in her inquiry instruction. This research contributed to the foundation of the next phase of this research program, which entailed the development and study of the use of an innovative genre of text—text that was written as a scientist's notebook and was specifically designed to support children and teachers to approach text as an inquiry. We then proceed to describe an experimental study comparing student learning from two forms of text. One form was the innovative genre, and the second was a considerate nonrefutational expository text (Armbruster, 1992). We conclude with a discussion of issues that have emerged in the course of this program of research.

What Is Known About Text in Science?

If we conceive of the knowledge base regarding science text in terms of three intersecting circles, with one circle representing text features, a second representing student use of text, and a third representing text in context, two circles have been fairly well developed (text features, student use of text), one is sparse (text in context), and the intersection of these three circles is virtually empty. Studies of naturally occurring science text offer a dismal picture of material that is characterized as dense and abstruse (Koch & Eckstein, 1995), incomplete in the provision of explanations (Lloyd & Mitchell, 1989), and sparse with regard to transitions and other devices useful to attaining cohesion (Anderson & Armbruster, 1984; Farris, Kissinger, & Thompson, 1988; Woodward & Noell, 1991). The poor state of affairs regarding naturally occurring text could, in part, be addressed by the research that has been conducted to examine the relative benefits of designing science text with specific features.

For example, there have been numerous studies (reported in a meta-analysis by Guzetti, Snyder, & Glass, 1992) that suggest that refutational expository text—that is, text that explicitly identifies and refutes misconceptions—is more effective (particularly when it is written in a considerate fashion) than nonrefutational text. However, it is seldom the case that widely available science text has been written in this style; researchers typically generate very short and focused segments of text for the purpose of investigating the effectiveness of refutational text.

One manipulation of text that has captured the interest of researchers is the insertion of embedded questions within the text. For example, Leonard (1987) studied the efficacy of placing questions at the beginnings of paragraphs in a college biology text, and calling attention to these questions through the use of an array of devices (use of upper case vs. underlining), when compared with a no-question text. Leonard observed that students who studied from the text with the embedded questions performed significantly better on tests of immediate recall than students in the no-question condition; however, there were no differences on the assessments that were administered four weeks later to determine maintenance of the information read. Balluerka (1995) studied the differential effects of providing an advance organizer, engaging students in the generation of an advance organizer, and the provision of illustrations highlighting main ideas in the text. The outcomes were assessed using two types of tasks: the recall of information and the application of information. The findings suggested that illustrations of key ideas facilitated the recall of information, whereas the deeper processing in which students engaged to generate outlines enhanced comprehension.

Another line of research examines what students do as they read and study from science text. Generally, this research suggests that that, left to their own devices, students do not know how to study and learn from scientific expository text (Craig & Yore, 1996; Dee-Lucas & Larkin, 1988; Otero & Campanario, 1990). For example, in the study by Boyle and Maloney (1991), even fairly sophisticated high school physics students did not effectively use explicit information regarding Newton's third law which was provided them via text, even though it would have facilitated their problem-solving regarding the application of forces on an object.

Attempts to teach students to engage more effectively with text through the use of strategies has produced mixed findings. For example, Pearson (1991), working with college students, found that although self-questioning enhanced performance on assessments that measure the short-term recall of information, it did not reliably enhance long-term retention of scientific concepts. In contrast, Woloshyn, Paivo, and Pressley (1994) observed that upper elementary students who were encouraged to elaborate on new information they were presented in text by drawing on relevant background knowledge, performed better on assessments of conceptual understanding, even when their prior knowledge was not scientifically accurate.

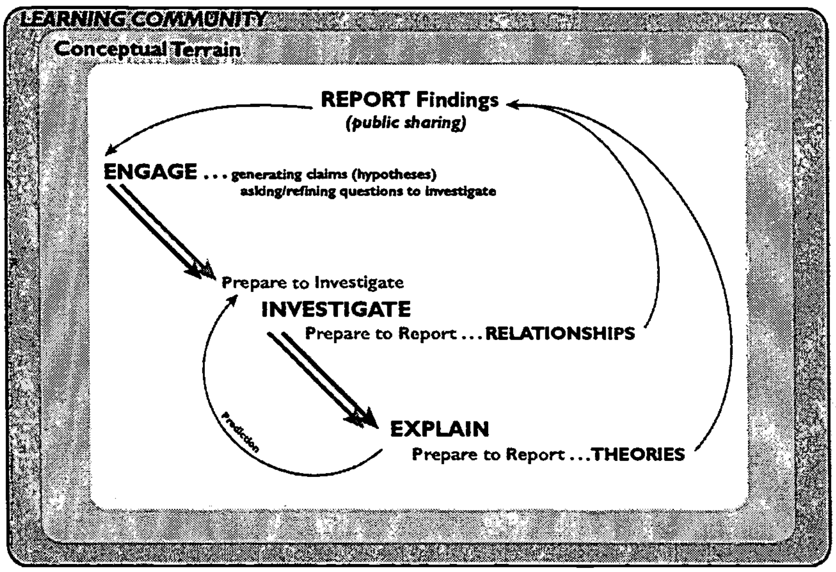
Generally, the majority of research regarding text in science has been conducted at the secondary and post-secondary levels. Much of this research has been conducted with the use of contrived text, and little of it has been conducted in the context of naturally occurring science instruction. One line of research that is more closely aligned with the research reported in this chapter is the work of Guthrie and Gaskins and their colleagues (Gaskins et al., 1994; Guthrie, MacGough, Bennett, & Rice, 1996). In a program of research entitled *Concept-Oriented Reading Instruction,* they have investigated the enactment of yearlong curricula in which elementary-age students and their teachers pursue the study of conceptual issues of the students' choosing. In the course of their inquiry regarding these topics, students are supported to find relevant resources, learn how to use these resources, and learn how to communicate their learning to others. The evaluation of this approach has been conducted using broad ranging assessments that include: breadth and amount of reading activity, student motivation for reading, cognitive strategies for reading, and the attainment of conceptual knowledge (defined very generally). This is a very ambitious program of research that clearly will inform a large set of significant issues regarding the role of text in inquiry instruction; however, the grain size of the analyses are such that they contribute little to our understanding of the specific nature of the texts students are using, how teachers are mediating students' use of these texts, and what understandings children are achieving that can inform our thinking about the role of text in advancing both conceptual understanding and scientific reasoning.

The program of research in the current study is an attempt to understand how various text features impact the use of texts by students and teachers in the context of inquiry instruction in elementary science teaching. The program began with the conduct of naturalistic observations of the ways in which elementary teachers, engaged in guided inquiry teaching, used text/secondhand investigations in the course of their teaching. This was followed by a descriptive study of one third-grade teacher for whom we designed a text to complement the firsthand investigation in which her class was engaged. When we began this program of research, we had a fairly clear idea of the nature and role of secondhand investigations; however, our work with teachers was designed to refine our thinking and to inform our understanding of how we could best support teachers to conjoin first- and secondhand investigations. Indeed, this initial phase of the research led us to the design of an innovative text genre that was designed to scaffold children's and teachers' use of text in an inquiry fashion. The second phase of the research was a quasi-experimental study intended to compare the outcomes of using the innovative text with the outcomes of a more traditional text. Finally, we engaged in an instructional study in which two fourth-grade teachers used the innovative texts in the course of a program of study called *How Light Interacts With Objects*. We begin by describing the professional development context in which this research is occurring.

The Professional Development Context Supporting This Program of Research

Before we proceed with the description of our research program, a word is in order regarding the professional development context in which this work is taking place. This context is important because it has afforded us the opportunity to conduct this research informed by teachers' experiences. For the past three years, we have worked with a group of K–5 teachers[1] who joined this professional development project for the purpose of learning how to effectively teach science from a guided inquiry perspective. Our work together has involved biweekly meetings during the school year, weeklong institutes during summers, and many hours working alongside these teachers in their classrooms. We refer to the context in which we are conducting our research as The *Guided Inquiry supporting Multiple Literacies (GIsML) Community of Practice*. Informed by sociocultural theory regarding the interdependence of social and individual processes in the co-construction of knowledge (John-Steiner & Mann, 1996; Rogoff, 1994), this professional development project has been designed to provide occasions for interaction, joint deliberation, and the collective pursuit of shared goals, particularly with regard to the teaching of science in the elementary grades.[2] (For a complete description of this professional development effort, see Palincsar, Magnusson, Marano, Ford, & Brown, 1998). The teachers represent 14 schools in six districts, one of which serves a rural community, two of which serve urban communities, and three of which serve primarily suburban communities.

Figure 1: The GIsML heuristic.



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Our focus has been on identifying practices that are consistent with a particular orientation to the teaching of science in the elementary grades. Informed by the research of Grossman (1990), we use the notion of orientation to refer to an overarching conception of how to teach a particular subject. An orientation can be thought of as a conceptual map that guides decision-making regarding curriculum, instruction, student understanding, and assessment. The orientation to which we refer is reflected in the heuristic presented in Figure 1. (For a more complete description of this heuristic and the instructional implications, see Magnusson & Palincsar, 1995). The heuristic is organized according to phases of instruction set within a particular problem space (e.g., a guiding question that is broad and identifies a general conceptual terrain: How does light interact with matter? Why do things sink and float?). Inquiry proceeds through cycles of investigation guided by specific questions (e.g., How does light interact with mirrors?) or a particular phenomenon (e.g., shaping a ball of clay to hold the most weight). Integral to this orientation is the conception of the classroom as a community of inquiry (cf. The Cognition and Technology Group at Vanderbilt, 1994; Wells, 1995). Hence, the examination and documentation of data gathered in the course of the investigation are conducted in pairs or small groups. Furthermore, a critical feature in the instruction is the reporting phase, during which the investigative teams share their data, speak to the evidence they have gathered to support or refute extant claims, and contribute new claims for the class's consideration.

The curved lines represent a cycling phenomenon in which students experience the same phase repeatedly in the same or different contexts. This is the recursive aspect of instruction that is required to promote meaningful learning—particularly with respect to scientific inquiry. For example, one needs repeated experiences examining natural relationships among phenomena before one can meaningfully test explanations for these phenomena.

In the course of GIsML instruction, students and teachers participate in two forms of investigation. Through *firsthand investigations*, children have experiences related to the phenomenon(a) they are investigating. In the course of *secondhand investigations,* children consult text for the purpose of learning about others' interpretations. The ultimate goal of GIsML instruction is to support children's learning of scientific understandings, and to enable students to experience, understand, and appreciate the ways in which these understandings have evolved by using the tools, language, and methods of reasoning that are characteristic of scientific literacy (Driver et al., 1994; Lemke, 1990; White & Frederiksen, 1998).

During the 1996-97 school year, the focus of the GIsML Community was on the design, enactment, and evaluation of firsthand investigations. In the spring of 1997, we piloted secondhand investigations in the classroom of a third-grade teacher who is a member of the Community, and in the summer of 1997, we formally introduced the idea of secondhand investigations to the Community. In the next section, we describe the outcomes of this phase of our research.

Descriptive Research on Secondhand Investigations

Prior research (e.g., Shymansky, Yore, & Good, 1991) has suggested that when teachers embrace activity-based, project-driven, or guided inquiry practices, text falls into a lacuna; however, this research has been conducted via survey and has not entailed direct observations of teachers who have been supported in the planning and enactment of guided inquiry teaching. As the teachers engaged in the GIsML Community of Practice enacted firsthand investigations with their students, we were interested in how teachers' thinking about the use of text would be influenced by their inquiry experiences. We observed that, though these teachers did not systematically introduce the use of text in these investigations, several teachers did in fact acquire topically related books from the library. One teacher used a folktale to introduce her first graders to the study of shadows, and there were many ways in which the teachers used print literacy, other than prepared text. For example, children's "wonderings" and class claims were posted throughout the room, and students were frequently asked to make and subsequently refer to notebook entries.

Conversations with the teachers about the role that secondhand investigations might play in inquiry provided helpful insights into why other researchers have reported the absence of text in inquiry teaching. Consensus quickly emerged among the teachers that there was a risk inherent in using text in that children might defer to the authority of the text, seeking answers from the text, when, in fact, the children themselves had a key role to play in working toward explanations and were quite capable of generating their own "answers" in the course of investigating phenomena. The teachers cautioned against introducing text early in the investigation and urged that text be used following a significant amount of firsthand inquiry. Hence, the preponderance of teachers' ideas suggested that text be used not to supplant children's inquiry and discourse, but rather to extend it. (For the full report of focus group conversations with teachers, see Palincsar & Magnusson, 1997.)

In preparation for the professional development work that we would do at the conclusion of this school year, we asked Sally Freeman, a third-grade teacher in the GIsML Community who was well recognized for her expertise as a language arts teacher, if she would be willing to pilot the use of secondhand investigations in GIsML instruction. As a research group, we had now observed 17 iterations of GIsML teaching on the topic of light, which gave us a fairly informed understanding about the role that text might play in this program of study. Ms. Freeman's class first engaged in a week of firsthand investigations of light, which proceeded in the following manner. As the engagement activity, Ms. Freeman asked her students to generate a list regarding what they knew about light. Based on their observations, the class next developed a set of claims regarding light that they would investigate with the use of light boxes and an array of materials, such as mirrors, translucent objects, objects of various colors, and prisms. Working in pairs, students then selected a claim from the list and investigated it with the materials. As they investigated, the students collected data in their notebooks to be presented to the remainder of the class during reporting. There were two iterations of the cycle of inquiry during this week-long investigation.

An annotated transcript of this instruction is included in Appendix A. In this next portion, we examine how Ms. Freeman led her students in this secondhand investigation. We do this because, although we already had a number of ideas regarding secondhand investigations, as indicated above, the experiences of this class were influential in our thinking about the features of text and of a secondhand investigation that would be most consonant with the GIsML orientation. The text Ms. Freeman used was specifically designed to reflect the experiences the students had garnered in their firsthand investigations; hence the reference to the use of a mirror as well as the inclusion of terminology that would help the students to characterize the phenomena they had experienced (e.g., absorption).[3] The question guiding this descriptive study was: What does the interplay of first- and secondhand investigations look like when a class is using nonrefutational expository text?

In discussing the discourse that unfolded in Ms. Freeman's class during the secondhand investigation, these are the features we will address: (a) The secondhand investigation was largely in the service of the firsthand investigations, (b) there was a seamless quality emerging between first- and secondhand investigations in this context, and (c) there was a metacognitive dimension to the discourse.

Consistently throughout the discourse, Ms. Freeman paid attention to using the text for the purpose of extending the students' firsthand inquiry. For example, Ms. Freeman focused the students' attentions on those claims for which there was still a lack of consensus. She began the secondhand investigation with the students' claims and models and continually tacked back and forth between the text and the student-generated claims. For example, when the text signaled that "light travels through some materials differently than others," Ms. Freeman stopped to inquire what the students already knew about this characteristic of light given their firsthand experiences. Similarly, when the text raised what is essentially a claim (when light hits black paper, almost no light bounces from it; instead, the light energy is absorbed), Ms. Freeman directed the students' attention to the evidence they had mustered for this claim from their own inquiry. Hynd and Alvermann and their colleagues (e.g., Alvermann & Hynd, 1989; Hynd, Qian, Ridgeway, & Pickle, 1992) have documented the important role that student dissatisfaction with existing knowledge plays in conceptual change. By engaging in the secondhand investigation so that it was essentially in the service of the firsthand investigation, the students' thinking remained at the forefront; the students' ideas were the touchstones, not to be usurped by the text.

There was a seamless quality relative to tacking between the students' experiences and the ideas presented in the text to determine knowledge claims. For example, when reading about luminous and nonluminous objects, and when reading about the properties of transparent, translucent, and opaque objects, the class was directed to explore their immediate environment for the purpose of identifying these phenomena. Further evidence of the seamlessness is presented in that portion of the discussion when Ms. Freeman incorporated the investigation and evidence generated by two students (Kevin and Ilya) and encouraged the class to respond to this evidence essentially as "text" (see Appendix A). The intertextuality is made more salient by the fact that Kevin read from his personal notebook at this point in the discussion. There is evidence that the students had already begun to appropriate this orientation to secondhand investigations. For example, even though Ms. Freeman was drawing the students' attention to whether the text had provided additional information regarding the speed of light, Nick offered additional evidence, drawing from the class's firsthand investigation ("Whenever we turned the light box on, the light immediately shot out"). Furthermore, the students used the text as an occasion for generating additional claims (e.g., the role that particles in the air play in reflection).

In addition, there was a metacognitive dimension to the discourse that merits attention. For example, Ms. Freeman was careful to make distinctions between first- and secondhand investigations. She made finer distinctions between those issues (represented as claims) that were unanswered (e.g., the nature of light as energy) and those issues that cannot be investigated firsthand (e.g., black holes). She labeled those claims for which there was not consensus (does water "split" [refract] light in the same way that a prism splits light?) as opposed to those on which there was consensus but for which there was insufficient evidence (dark objects absorb more light than lighter colored objects). She called the students' attention to what they already knew relative to the information in the text, and she signaled how the text might advance their emergent understandings of claims they had generated. Finally, this secondhand investigation revealed the role that text can play when students have had disparate firsthand experiences and yet the class is trying to advance class claims. Recall that the students in this class were free to investigate whatever claims regarding light that they were curious about and for which they had the necessary materials and equipment. The value of this approach is that, across the class, students had experienced a broad range of phenomena related to light (e.g., color derived from white light, the relationship between color and the absorption of light, the relationship between the texture of an object and the manner in which light reflects off that object). However, this range of experiences made it more difficult for students to achieve consensus regarding a particular set of claims about the behavior of light. The text, along with the diverse experiences of the students, provided a shared context in which the class could advance their consideration and judgment regarding a common set of claims. This finding is reflected on the measure of conceptual understanding that was conducted with these students before their firsthand experiences, following their firsthand experiences, and following their secondhand experiences. On the pretest concept measure, only 2 of the 27 students in this classroom correctly indicated (via drawing) that light (from the sun) is reflected off a target (in this case, a tree) and to the eyes of the viewer. Following their firsthand investigation, 16 students correctly identified how the viewer is able to see the tree. However, following the secondhand investigation, all but one student correctly responded to this question.

The descriptive research in Ms. Freeman's class advanced our understanding of the role that the text, teacher, the classroom community, and inquiry activity play in advancing students' scientific inquiry and conceptual understanding. The close study of one teacher's implementation of secondhand investigations was invaluable to informing our thinking about the challenges and opportunities inherent in achieving a productive intersection between text and firsthand investigations in the context of guided inquiry science teaching in the elementary grades. Although there were many positive and worthwhile experiences created in the conduct of this secondhand investigation, we were struck by those features that were missing and yet seemed integral to fully productive secondhand investigations. For example, children were not engaged in assuming a critical stance relative to the text, and the text seemed to do little to advance the children's opportunities to learn to think and reason scientifically. These observations influenced our thinking about the design features we would include in the innovative genre we developed to support secondhand investigations in GIsML instruction. Our goal was to design text that would assume some of the burden traditionally on the teacher to engage in the use of text for the broad range of purposes we had in mind.

Designing Text to Support Guided Inquiry Teaching

Our decision to model the text on a scientist's notebook was influenced by our interest in the role that secondhand investigations could play in advancing students' understandings related to both the topic under study (e.g., light), and the use of scientific reasoning through learning about the experiences and thinking of others. Toward this end, there are many ways in which the notebook represents a think-aloud on the part of Lesley who documents (a) the purpose of her investigation, (b) the question(s) guiding her inquiry, (c) the investigation procedures in which she is engaged, (d) the ways in which she is gathering and choosing to represent her data, (e) the claims emerging from her work, (f) the relationships among these claims and her evidence, (g) the conclusions she is deriving, and (h) the new questions that are emerging from her inquiry.

There are a number of features that are present in these texts that are consistent with promoting scientific literacy. In particular, these features are consistent with advancing reasoning about concepts/phenomena as scientists do. The texts include multiple ways of representing data, including tables, figures, and diagrams. For example, diagrams are used to illustrate the set-up of the investigation materials. Figures are used to depict data that students can interpret along with the scientist. Tables model the various ways in which data can be arrayed, and the narrative accompanying the table models the activity of interpreting these data.

In addition to these structural features, there are a number of substantive features that we include in these texts. For example, there are opportunities for the scientist to revise her thinking based on the collection of additional or more specific data. Students are supported in tracing the source and nature of these revisions. There are reference materials included in these texts that serve to advance the inquiry. For example, in a notebook entry regarding light, the scientist includes what she has learned from studying Newton's investigations of light and color. This provides the opportunity for the scientist to model the use of a secondhand investigation as she critically reads and interprets the reference information and indicates how she will formulate claims from this information to advance her own inquiry. These reference materials are also useful to enriching the conceptual information with which children can work.

Yet another feature of these notebooks is the extent to which they portray the ways scientists interact with one another and observe particular conventions to facilitate these interactions. For example, in one entry Lesley notes that fellow scientists were not persuaded by her data because they were inexact, leading her to use an instrument that will provide more exact data and a process that can be more readily replicated.

One of the features that students have frequently commented on with regard to these texts is the presence of "voice" in these notebooks. As the quotes with which we opened this manuscript suggest, students equate the reading of these texts to learning from a "real person," and have suggested that this feature personalizes their reading and renders the text more interesting to them. Finally, we note that these texts have been designed in conjunction with the inquiry programs of study in use in our GIsML classrooms (i.e., *How Light Interacts With Objects*, *The Study of Floating and Sinking*, *The Study of Soils*). In summary, the innovative texts that we have been designing and investigating are a hybrid of exposition, narration, description, and argumentation. In the next section of this chapter, we describe a quasi-experimental study in which we compared the outcomes of using this innovative text with the outcomes of using considerate, expository text.

Experimental Research Comparing the Innovative Text With Traditional Text

The purpose of this quasi-experimental research was to compare the process and outcomes of using the innovative text with those using considerate-expository (C-expository) text to support a secondhand investigation, in the absence of any firsthand experiences. The innovative text was again modeled after the scientist's notebook and contained the features described above. The C-expository text was designed as a considerate, nonrefutational, expository text. We elected to design this study as a within-subject, across-group study in which each child would serve as his or her own control and would read both the notebook and traditional version of a text. Recognizing the role that background knowledge plays in comprehension, both versions of the text addressed the general topic of light. Both a notebook and traditional text were constructed for the subtopic *reflection*, and both a notebook and traditional text were constructed for the subtopic *refraction*. Children who read the notebook version of reflection read the C-expository version of refraction, and vice versa.

Methods

Context

This study took place in two waves. The first wave began in late October in Granite City. The classroom teachers in three fourth-grade classrooms, all of which were located in different schools in this district, agreed to participate. Our inability to identify a fourth classroom for this wave meant that the design was incomplete; there was no condition in which the students first read the C-expository refraction text followed by the notebook reflection text. The second wave began in February. This wave took place in one school in Maple Grove, in which four fourth-grade teachers agreed to participate; hence, for this wave we had a complete design.

Table 1: Demographics of Two Participating Districts

District	Enrollment	% Free/ Reduced Lunch	% Urban	% of Students: White	Black	Am. Ind.	Asian	Hispanic
Granite City	3,091	51.6%	100%	66.3	30.3	0.3	0	3.0
Maple Grove	2,400	14.5%	0%	91.5	8.0	0.5	0	0

Participants

The demographics for each of the two districts are presented in Table 1, followed by Tables 2 and 3, which include descriptive information regarding the participating classrooms. As Table 1 suggests, there are important differences in the characteristics of these two districts. Granite City is an urban district that serves a significant number of families that qualify for free or reduced lunch, whereas Maple Grove is a rural district with many fewer families in financial distress. The racial/ethnic profile of Maple Grove is fairly homogenous, whereas Granite City is somewhat heterogeneous, with a significant population of self-identified African Americans. Furthermore, as the information in Tables 2 and 3 suggest, there were potentially important differences in the characteristics of the participating classrooms within the two districts. The Gates scores (across both vocabulary and comprehension) are consistently lower in Granite City schools than in the Maple Grove schools. Because of these sets of differences, we report the results for each district.

Table 2: Data Regarding Classrooms in Granite City District

Class	N	Gates-Maginitie Vocabulary Standard Score	Gates-Maginitie Comprehension Standard Score	*Reflection* Pretest Mean Raw Score	*Reraction* Pretest Mean Raw Score
1	24	4.13	4.04	2.56	1.86
2	24	4.04	4.08	2.12	1.29
3	22	1.94	2.00	1.45	1.45

Table 3: Data Regarding Classrooms in Maple Grove District

Class	N	Gates-M Vocabulary Standard Score	Gates-Maginitie Comprehension Standard Score	*Reflection* Pretest Mean Raw Score	*Reraction* Pretest Mean Raw Score
1	23	4.54	4.76	2.20	1.15
2	23	4.48	4.37	2.47	1.47
3	27	5.15	5.69	3.33	2.29
4	26	4.40	5.08	2.44	1.92

Materials

The texts. Table 4 represents the characteristics of the two text types across the two topics. We attempted to hold similar all features of the text (e.g., overall length, number of propositional units, readability) that might interfere with our ability to study the differential effects of the features in which we were most interested (those modeling scientific reasoning and the use of inquiry to advance scientific understanding). These features are best represented in the propositional units that are characterized as syntactic versus substantive. Substantive units refer to those statements that were written to inform the children's understanding about the reflection or refraction of light (e.g., "the texture of an object will affect the direction that the light is reflected...", or "light is energy"). Syntactic units are those that communicate the process and nature of scientific reasoning (e.g., "I need to think about how this information helps me to understand my own data and to answer my questions").

Table 4: Characteristics of the Two Text Types

Text	# Sentences	# Propositional Units		Readability	Figures	Tables
		Substantive	Syntactic			
Reflection Notebook	25	18	14	mid grade 5	2	1
Refraction Notebook	23	18	15	beg. grade 5	3	1
Reflection Traditional	25	30	0	late grade 5	2	0
Refraction Traditional	28	31	0	beg. grade 5	3	0

The assessments. For each of the two subtopics, we designed a paper and pencil assessment to be administered before and after the students read each text. There were seven items on each assessment (some with multiple parts, totalling 14 points). Of these items, three were designed to measure the recall of factual information. The remaining items were designed to assess students' ability to engage in inferencing from the text. With respect to the items requiring inference, two dealt solely with substantive knowledge and two with a combination of substantive and syntactic knowledge (the ability to engage in scientific reasoning). For example, on the refraction assessment, students were provided a table with the optical densities of five materials (glass and four other materials). They were asked to indicate which material would bend light the most when the light was moving into this material from glass. The concept of optical density was described in the text; however, to be successful on this item, students needed to (a) know how to read the data represented in the table, (b) be able to compare the materials as relevant to the issue of optical density, and (c) complete the comparisons required to determine which material would bend light to the greatest extent.

Instruction

Given the different affordances of the two text types, it was important to consider the relationship between the text and the instruction. We did not expect students to read and respond to these texts independently; rather, the students' reading of the text would be mediated by the teacher (Palincsar). This was decided based upon the following: (a) It would be uncommon for fourth-grade teachers to assign such text to be read independently, and (b) we did not want students' ability to decode the text to limit what we could determine about their learning from the text. Hence, we were interested in determining how the characteristics of these two text types would interact with the teacher's and students' use of these texts.

With the C-expository text, the teacher employed domain-general strategies; that is, with each paragraph, the teacher elicited a summary in which the students were encouraged to identify the main ideas. The students were also asked to identify the questions that were addressed in the paragraph, and they were asked if any information presented in the paragraph required clarification. When using the notebook text, the teacher mirrored the activities suggested in the GIsML heuristic. At the beginning of the text, the teacher asked the students to identify the purpose of the inquiry. As the text continued, the teacher engaged the students in identifying the investigative procedures, interpreting the data, examining the relationships among the data, and identifying the implications of these relationships with regard to claims they might make.

Research Design and Procedures

Design. We chose to use a within-subject, across-group design in which each student would experience both genres of text. In each wave, the classes were randomly assigned to first experience one of four possible conditions: notebook/reflection, C-expository/reflection, notebook/refraction, C-expository/refraction, followed by assignment to the alternative genre/topic condition.

Data collection. Two weeks before the first text was to be introduced in each classroom, the Gates-MacGinitie reading tests were administered in two sessions (one for the vocabulary and the second for the comprehension). A week later, the two pretests assessing conceptual understanding related to reflection and refraction were administered, counterbalanced for order across each classroom. These assessments were read aloud as the students recorded their responses, and the students were encouraged to spell unfamiliar words the way that they sound.

Instructional procedures. One week after the assessments of conceptual understanding were administered, the students were introduced to the first text. Text type and topic were counterbalanced across each classroom. The instruction (described above) took 40 minutes and was immediately followed by the administration of the topic-appropriate postassessment of conceptual understanding. A week later, the students were introduced to the alternate text type/subtopic and took the last assessment of conceptual understanding.

Data coding. The pre- and postassessments were scored blind with regard to the text genre. In addition, 25% of the data were coded by two raters for the purpose of establishing 100% interrater reliability.

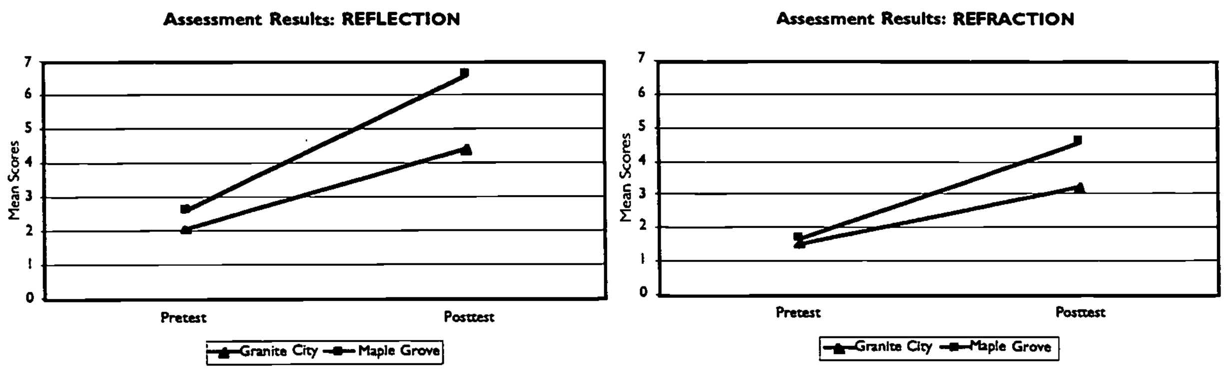
Results and Discussion

Descriptive Statistics

Our initial examination of the data concerned the variance in the sample with respect to the test scores. Due to the relatively small sample size and the discernable differences in the scores for some of the comparisons of interest, we sought to test the assumption of homogeneity of variance, which is a key assumption for the use of parametric statistical tests. Using Levene's test for equality of variance, results indicated unequal variances for some but not all comparisons of interest in the data; however, we decided to take the conservative route and use nonparametric statistics for all comparisons. Our second examination of the data concerned the comparability of the data collected in different contexts. For example, we were concerned about differences in the pretest data by topic, which would suggest the need to keep by data separate by topic rather than combining the data to examine the influence of the genre. A test of mean differences—Wilcoxon Matched-Pairs Signed-Ranks Test, 2-tailed—indicated that the pretest data by topic were statistically significantly different (p = .0000). Thus, the question of the influence of genre on knowledge construction had to be considered separately for each topic. We were also concerned about differences in the scores by district. Statistical tests (Wilcoxon Matched-Pairs Signed-Ranks Test, 2-tailed) indicated no significant differences in pretest scores between Granite City and Maple Grove, but posttest scores and change scores were statistically significantly different (Mann-Whitney U, 2-tailed), in favor of Granite City (reflection—post, p = .0000; reflection—change, p = .0008; refraction—post, p = .0001; refraction—change, p = .0009). Considering that these districts have very different student populations (rural vs. urban, respectively) and that the study was conducted at different times of year (mid-fall vs. late winter, respectively) we decided to examine the data separately for each district.

The following graphs show the assessment data for each district by each topic.

Figure 2: Results of the assessment data for the total sample by topic area.

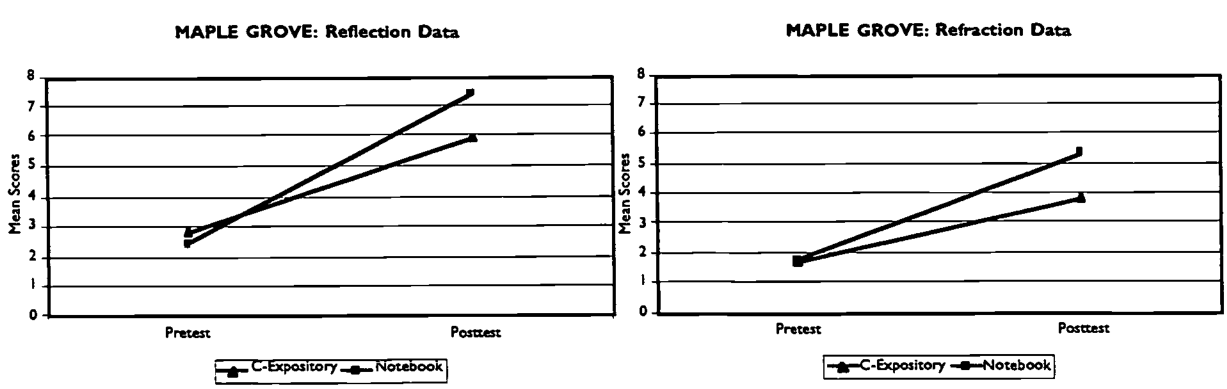


Results from the Maple Grove sample

After disaggregating the data by district, we reexamined the question of whether the data could be combined across topics. Comparisons of pretest scores for reflection versus refraction for the Maple Grove sample indicated statistically significant differences in favor of reflection (Wilcoxon Matched-Pairs Signed-Ranks Test, 2-tailed, p = .0000). These results led us to disaggregate the Maple Grove data by topic.

A second comparison dealt with determining whether the means of the pretest scores for the students who experienced the different text genres were similar enough statistically to allow comparison of the students' posttest scores. For both the reflection data (Mann-Whitney U, 2-tailed, p = .2132) and the refraction data (Mann-Whitney U, 2-tailed, p = .5611), pretest scores were not statistically different. Thus, we could fairly conduct comparisons of the knowledge growth as shown in the posttest scores for the Granite City students when they read the notebook text versus when they read the C-expository text. Figure 3 shows the Maple Grove results for each topic.

Figure 3: Results of the assessment data for Maple Grove.



Reflection. Statistical comparisons by genre were calculated for both the posttest scores and change scores from pre- to posttest on the reflection assessment (Mann-Whitney U, 2-tailed). For Maple Grove, both comparisons were statistically significantly different for this topic area (posttest, p = .0212; change, p = .0016). Thus, these data indicated that text genre did make a difference in the knowledge that students developed from reading, with the result that when students read the notebook text they learned more about reflection than when they read the C-expository text.

Additional analyses were conducted to examine the assessment data by type of item—the five items that were purely substantive items in that they only addressed concepts about light and reflection, versus the two items that were substantive and syntactic in that correct responses also required students to employ scientific reasoning. These latter types of items shall from this point on be referred to as syntactic items. In both cases, pretest scores showed no statistically significant difference by genre (Mann-Whitney U, 2-tailed; p = .2792 and p = .1360, respectively). Posttest score comparisons in both cases were statistically significantly different in favor of the notebook text (Mann-Whitney U, 2-tailed; p = .0244 and p = .0277, respectively). Thus, when students read the reflection notebook text, they outperformed those reading the C-expository text both with respect to substantive items and with respect to syntactic items regarding reflection.

Refraction. Statistical comparisons by genre were also calculated for the posttest scores and change scores on the refraction assessment, and again both comparisons were statistically significantly different for this topic area (Mann-Whitney U, 2-tailed; posttest, p = .0064; change, p = .0019). Thus, these data regarding refraction also indicated that the genre did make a difference and that students in Maple Grove learned more about refraction when they read the notebook text than when they read the C-expository text.

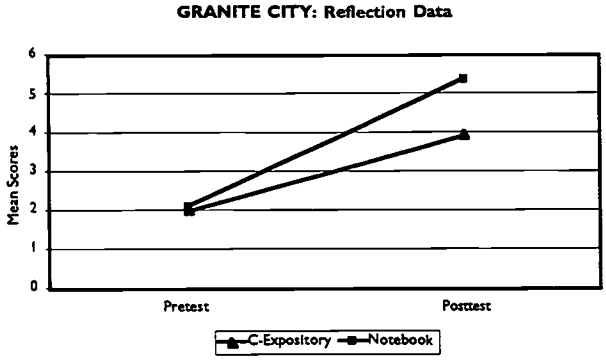
Additional analyses were also conducted by type of item for the refraction assessment, which similarly contained five substantive items and two syntactic items. For these data as well, pretest scores showed no statistically significant difference by genre in either case (Mann-Whitney U, 2-tailed; p = .7959 and p = .8129 for substantive and syntactic, respectively). Regarding posttest score comparisons, again, in both cases mean scores were statistically significantly different in favor of the notebook text (Mann-Whitney U, 2-tailed; p = .0215 and p = .0205, respectively). Thus, when students read the notebook text they outperformed those reading the C-expository text with respect to both substantive and syntactic items regarding refraction.

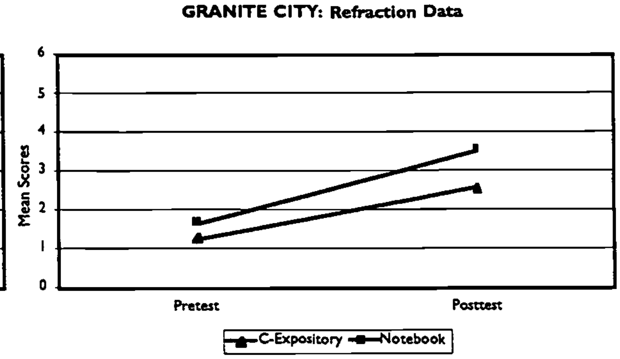
Results from the Granite City sample

The data from Granite City were also evaluated with respect to whether the relationship between genre and learning could be examined regardless of topic or whether it required separate comparisons. Comparisons of pretest scores for reflection and refraction indicated statistically significant differences in favor of reflection (Mann-Whitney U, 2-tailed, p = .0000); hence, all analyses were conducted separately by topic.

Similarly, pretest scores for all students in this sample were compared to determine whether comparisons of posttest scores by genre would be meaningful. For both the reflection data (Mann-Whitney U, 2-tailed, p = .7765) and the refraction data (Mann-Whitney U, 2-tailed, p = .2276), pretest scores were not statistically different. Thus, we could fairly conduct comparisons of the posttest scores indicating knowledge growth for the Granite City students when they read the notebook text versus when they read the C-expository text. Figure 4 shows the Granite City results for each topic.

Figure 4: Results of the assessment data for Granite City.





Reflection. Statistical comparisons by genre for the posttest scores and change scores for Granite City were not statistically significantly different for this topic area (Mann-Whitney U, 2-tailed; posttest, $p = .4418$; change, $p = .2586$). Thus, the difference in text genre did not seem to make a difference in the knowledge that Granite City students developed from reading about reflection. One explanation for the lack of difference in this district compared to the other is that, due to the incomplete design in this district, which heightened the differences in cell sizes, there was little statistical power to detect differences. Additional analyses conducted to examine the assessment data by type of item indicated no differences by genre for pretest scores (Mann-Whitney U, 2-tailed; $p = .8488$ and $p = .5344$, respectively). Posttest score comparisons approached statistical significance in favor of the notebook text for the syntactic items (Mann-Whitney U, 2-tailed, $p = .1059$) but not for the substantive items (Mann-Whitney U, 2-tailed, $p = .4790$). Thus, when students read the reflection notebook text, they tended to do better on the syntactic items than those who read the C-expository text, but there was no difference in performance relative to the substantive items.

Refraction. Statistical comparisons by genre were also calculated for the posttest scores and change scores on the refraction assessment, and this time, the comparison for posttest scores but not change scores were statistically significantly different for this topic area (Mann-Whitney U, 2-tailed; posttest, $p = .0405$; change, $p = .2826$). Thus, there was some evidence that the difference in text genre did make a difference in the knowledge that students developed from reading about refraction, in favor of the notebook text. The lack of statistical significance relative to the change score difference can be attributed to the fact that the variance of the change scores was very large.

Additional analyses were also conducted by type of item for the refraction assessment, which similarly contained five substantive items and two syntactic items. For these data as well, pretest scores showed no statistically significant difference in pretest scores by genre in either case (Mann-Whitney U, 2-tailed; $p = .7959$ and $p = .8129$ for substantive and syntactic, respectively). Regarding posttest score comparisons, no differences were statistically significant (Mann-Whitney U, 2-tailed; substantive $p = .2489$ and syntactic $p = .1420$). Thus, when reading about refraction, the text genre did not make a difference regarding what was learned relative to particular types of items.

Summary

In summary, both versions of the text were supportive of students' learning across the two topics concerning light; however, in three of the four conditions in which we could compare the relative benefits of the text genre, the results favored the notebook genre. In one sample (Granite City) for one topic (reflection), there was no significant difference between the outcomes for students who learned about reflection using the notebook vs. the C-expository text.

To fully understand these differences in outcomes is to examine the nature of the instructional interactions supported by these two text types. Generally, across the seven classrooms, when the notebook text was in use, the instructional conversation reflected the inquiry process. Students were prompted to reflect on the text in terms of the inquiry reported in Lesley's notebook, and across the classes, the students were able to draw upon the substantive information in the text to not only follow but also to anticipate the inquiry that was subsequently described. For example, in the refraction notebook version, the text provided opportunities for the students to draw upon their relevant background knowledge to generate explanations for an observation quite familiar to them—the appearance that a straw in water is "broken" at the point it enters the water. Because the text was written as an ongoing inquiry, students responded to their reading by bringing their own experiences to bear with this type of phenomenon, making suggestions about how Lesley could proceed to further investigate the phenomenon in other contexts. This type of conversation was far less likely to occur during the reading of the C-expository text in which the phenomenon and its explanation were presented explicitly for the students and then illustrated in additional contexts.[4]

Finally, there were substantially more opportunities for students to engage in co-construction relative to understanding light when responding to the notebook version. For example, the notebook text about reflection provided information in a table about the characteristics of given materials (i.e., color, texture) and the interaction of light with each. Students had to hypothesize about the relationship between the characteristics of objects and the behavior of light. In contrast, in the C-expository version, students were provided with a description of the relationship, which they then paraphrased; however, this did not engage them in the same construction relative to building conceptual understanding about light.

In the final portion of this report, we present a subset of findings from an observational study conducted in two fourth-grade classrooms as teachers used several notebook texts to engage their students in secondhand investigations that complemented their firsthand inquiries.

Observational Research With the Innovative Text

In her dissertation study, Danielle Ford has examined the experiences of two fourth-grade teachers and their students as they engaged in firsthand investigations in a program of study entitled How Light Interacts With Objects and secondhand investigations using two notebook texts designed for this program of study.

In this section, we highlight a few of the findings from her research, drawing upon the experiences of Ms. Swanson and her class. (The reader is referred to Ford, 1999, for complete information regarding this work.)[5] As we engage in this research, we are especially interested in ascertaining the instructional opportunities afforded by the text, those features of the text that were most challenging, and the relationship between the first- and secondhand investigations. For the purpose of this paper, we are interested in reporting those observations that are influencing our current thinking about the design of these texts.

Ford made a number of observations regarding the ways in which these teachers made use of the structural features of the text. For example, these texts contained several tables and figures to which the teachers devoted considerable time, guiding students in thinking about why these features were included and how they might be used. This is an interesting finding to the extent that the ability to interpret data that are presented in tables and figures is integral to the comprehension of scientific texts (Roth & McGinn, 1998).

Ms. Swanson	Why do you think she [Lesley] gave us this picture?
Ann	I think she wanted us to understand her thinking, so she put pictures and labeled it. So we would understand what she was thinking. Not just the words. It's kinda like what we were doing for our investigations, because we said that we wanted them (peers) to put pictures on theirs [posters] and words and to label them so we would understand. And that's what she's doing.

One of the most obvious ways in which the text influenced the children's thinking was when they returned to conduct another cycle of their own firsthand investigations following their initial secondhand investigation. The students were very attentive to the organization and representation of their data, drawing heavily on the formatting ideas presented in the scientist's notebook. In addition, they quickly appropriated the idea of quantifying the amount of light, adopting the same scale introduced by Lesley.

The secondhand investigation also appeared to be an effective means of introducing the students to a more precise lexicon with which to describe their own observations regarding light. For example, following the reading, the students revised the list of class claims appropriating the terms "absorbed" and "transmitted" to substitute for "stays in" and "goes through."

We purposefully designed the text to report findings that would be revised upon further investigation. This feature led to one of the most interesting exchanges to occur in the course of the secondhand investigation, when there was a conflict between a class claim that had received widespread support following the students' firsthand investigations (i.e., light reflects off all objects) and data that were presented by Lesley in her notebook (i.e., these data suggested that light did not reflect off a piece of black felt). In the beginning of this exchange, Nat, who is leading the discussion, summarizes and then follows with a question that is focused on the conflicting finding:

Nat	I think on this table what they're trying to tell us is how the objects went with light, and how the shadow was and how it behaved. And my question is, why did the black felt have no light? Byron?
Byron	Cause it was really hard for it to reflect and go into the light catcher.

Mitch, another student in the class, is disturbed with this finding.

Mitch	That's not true! Cause it says light can reflect off anything [pointing to the class claim that has been posted on the wall]
Ms. S	Hold on! What does it say there [on the table]?
Mitch	On reflected, it says "no light."
Ms. S	What does that mean?
	...
Mitch	That she don't believe that light reflects off everything.
Ms. S	Okay, so she wouldn't believe one of our claims.

This incongruity led the children to speculate why it might be that Lesley's observation differed from their own. Among their speculations were the possibility that the black felt with which she was investigating was different than their own and (pointing to the figure that Lesley provided of her experimental set-up) noticing that her light catcher was not placed as closely to the object as were their light catchers. As Lesley proceeds with her investigation she is advised by other scientists to use a light meter for the purposes of obtaining more accurate data.

Ms. S	So, this is a pretty important thing. If you've got a group of scientists, and you're sharing, and they want something else from you. Do they just say, well, Lesley, we're not convinced?
	...
Becca	One of the scientists said for her to use a light meter. They were trying to help her to get more data by one of the scientists saying she could use a light meter.... The scientists weren't saying she was wrong or not right.
Ms. S	They actually did a couple of things. They were very specific about what they wanted more from here. They told her they wanted to know more about the amount of light reflected from an object compared to the amount of light transmitted from an object. That's what they wanted her to focus on. And they said, you know, it's not exact, and here's an idea of what you might want to use to go back and make it more exact.

The students were immensely pleased when, with the use of this instrument, Lesley also measured reflected light from the black felt.

Similar to the findings of Dunbar and Klahr (1989), Ford also found that students were challenged in distinguishing among evidence, claims, and data. In the presentations regarding their own firsthand investigations, as well as in their interpretations and discussions of Lesley's inquiry, these constructs were not used with rigor. Furthermore, consistent with the findings of Kuhn (1989) and Schauble & Glaser (1990), although students were fairly adept at identifying those data that supported their claims, they paid little attention to the role of disconfirming evidence. In addition, claims for which there was no evidence were dropped from the class conversation.

As we reflect on findings such as these, we are intrigued with additional possibilities that might be featured in the text. For example, we are interested in the modeling of scientific argumentation in more explicit ways. This is especially relevant if the text exploits the firsthand experiences that students have engaged in so that they are in a position to co-construct the argument with the scientist, or to deconstruct another's argument. We will continue to pursue the use of these texts to present the norms and conventions of scientific problem-solving and to demonstrate the social ways in which the canon is generated and refined over time.

Conclusion

This multifaceted program of research has both shaped and supported our thinking about the role and nature of secondhand investigations in advancing elementary children's learning of scientific knowledge and reasoning. The early observational work in Ms. Freeman's room, which led to the development of the notebook genre, changed our thinking about the possibilities with text in inquiry instruction in unexpected ways. This research revealed a number of the challenges inherent in conducting secondhand investigations, particularly at the elementary level, where children may have had relatively few experiences using informational text. These challenges included the need to teach students to use text generatively, assume a critical stance relative to text, monitor their understanding of text, and build connections between the information presented in the text and the understandings they developed from their firsthand investigations. Teachers face the additional challenge posed by the paucity of commercially prepared text material that can productively support this kind of secondhand inquiry. This paucity, along with thinking about the challenges of secondhand investigations, led us to consider designing our own text, which resulted in the scientist's notebook genre. The quasi-experimental work provided sufficient support for the benefit of the notebook genre over more traditional text to lead us to continue investigating both the instructional possibilities and learning outcomes with this new genre.

Furthermore, the quasi-experimental research and the later observational work represent an initial response to concerns expressed by teachers who are experienced with guided inquiry science teaching about the value-added of secondhand investigations. They expressed concerns that text not supplant the important learning that students could experience in the course of firsthand inquiry, such as examining data for patterns, determining how data constitute evidence and counterevidence for extant claims, thinking through the process of representing one's data and interpreting others' data, and designing further inquiry experiences. In addition, these studies shaped our thinking about additional features to further enhance the ways the text could support students in developing knowledge of and facility with scientific reasoning.

Like White and Frederiksen (1998), who suggested that their software, ThinkerTools, is a valuable way of scaffolding the initial implementation of a guided inquiry curriculum, we believe that the innovative text genre that assumes the form of a scientists' notebook can be an effective way of scaffolding both students' and teachers' use of text in an inquiry fashion. We are planning future research to investigate this very issue: Does the use of the notebook genre influence the ways teachers and students use commercially prepared text? We are also interested in how we might exploit the design of notebook texts for the purpose of supporting children's learning of some of the more challenging aspects of scientific reasoning, such as coordinating data, evidence, and claims in the service of constructing a sound scientific argument. These texts might also be used to engage students in the process of evaluating multiple explanations for both accuracy and parsimony. In addition, we are interested in exploring further the interplay of first- and secondhand investigations. For example, our preliminary data suggest that strategically experienced secondhand investigations can have a productive influence on the ways children enact and learn from firsthand investigations. We have seen that secondhand investigations suggest strategies to children regarding how they might most effectively represent their data during firsthand investigations. Similarly, in the course of secondhand investigations, we have observed that children begin to develop a shared lexicon for discussing their inquiries, either first- or secondhand.

In closing, our proposed research program is situated at a promising intersection. We believe that what we are learning at this intersection can advance inquiry-based teaching and learning of science in the elementary grades. In particular, three insights seem most promising as guidelines for instructional practice: (a) Conceptualizing instruction as guided inquiry teaching consisting of first- and secondhand experiences helps to contextualize the contribution each can make; (b) certain text features and genres (i.e., those that constitute the notebook genre) support the conduct of both first and secondhand investigations; and (c) classroom contexts must be intentionally and carefully structured in order to support effective inquiry-based teaching and meaningful learning via inquiry.

Appendix A: Annotated Transcript of Ms. Freeman's Class Engaged in Secondhand Investigation Regarding Light

SF:	Now, a week and a half ago, when we were doing our investigation of light, during that whole week a lot of questions came up that we found we couldn't answer with the materials we had in the classroom. Frequently people would say, "I guess we need to do that in a secondhand investigation." Do you remember hearing that?
Students:	Yeah.
SF:	OK, what were some of those things that were unanswered or that we felt we needed to do different kinds of investigations with? I thought I'd list a few on the board, just to keep a record of it. What were some of the things? Kyla?
Kyla:	Um, the speed of light.
SF:	OK. [*writes statement on the board*] I'll just make some quick notes on the board. So, speed of light was one. What else? Evan?
Evan:	If light is the fastest thing in the solar system.
	...
Sarah:	Um, light splitting
Katie:	[*whispering to Sarah, then growing louder*] Water splitting light as well as a prism.
Male student:	[*off camera*] Well, that's not a secondhand investigation.
Katie:	I know but we didn't—
SF:	But we didn't answer that question. OK [*writing on board*] water splitting light into colors. OK, what else? David.
David:	Well, we said this one, the person who said this one said it sorta messed up but we said light absorbs black. They tried to do that one but they said it sorta messed up a bit.
SF:	OK, is our claim about black absorbs or soaks up light?
David:	Yeah. Some people tried it and they couldn't get it to work.
	...
SF:	OK. [*writing on board*] White reflects light. OK, so we weren't sure about that. Someone tried to, to prove that but we weren't sure about that one. Nick?
Nick:	I bet black holes are called black holes because they suck in light. Black.
SF:	OK, so that was another thing we couldn't really do a firsthand investigation of. [Thank goodness.]
Students:	[*off camera*] Yeah/Yeah 'cause you can't like
SF:	OK, anything else? I want you to think a little longer. I have a few things I jotted down too when I was trying to recall. Actually, David Brown, you mentioned a couple of things that you couldn't investigate firsthand. [David B. has no respon se] Let's see if I have them written down. Oh, how about light as a source of energy?
Katie:	Oh, yeah. We kinda did that one.
SF:	How did we do that, Katie?
Katie:	We put like a thermometer [and we found]
Student:	[*off camera*] That's heat.

Katie: that it was a source of heat.

Nick: But heat isn't energy.

SF: And you thought that heat might prove that it was a source of energy. But we had some disagreement about whether—Nick—we had some disagreement about that. So can we put that down, that we're not sure about that yet? And we might need more. OK. [*writing on board*] Light is a source of energy. OK. Anything else? Ooo, Kevin and Ilya, I remember some controversy in your presentation. Do you remember what that was about?

...

Kevin: [*reading from journal*]
Light can be reflected by a mirror but not any object than a mirror.

SF: So, light isn't reflected by any object but a mirror. Does that say kind of what you're saying there? [*students are talking, "No," some general rumbling*] And we had a controversy about that. People had different opinions. [*writing on board*] Light isn't reflected by objects other than mirrors. All right, let's see if I have anything else here. [*checking notes*] I remember another one. We actually had a long discussion about whether things that, I think you were talking about this, Julian, and you were, Nick—about things that are, excuse me, are all things that glow hot?

Julian: Oh, yeah.

SF: Remember that discussion?

Julian: Everyone was talking about that.

SF: Hm-mm. [*writing on board*] [*Aside:* Nick, whatever you're eating, you need to stop, OK? Unless you have enough to share.] OK, and the shadow business. Ayaka had some evidence that we couldn't find at the last minute. Why do some objects make darker shadows than other objects? Do you think we needed some, some more information about that? [*no response from Ayaka*]

Student: [*off camera*] Ayaka didn't have hers so we couldn't really discuss it.

SF: Right. [*writing on board*] Some objects make darker shadows than others.

SF: OK, let's take a look at the article.

After this conversation, Ms. Freeman read the first part of the text, reprinted below, to the class.

> Light and Objects
>
> Everything that we see fits into one of two groups. In one group are objects that give off light. They are called ***luminous*** objects. Light bulbs, the sun, flashlights are examples of luminous objects. The other group of objects do not give off light. We can see them only because light from luminous objects bounces off them and travels to our eyes. These objects are called ***nonluminous*** objects.

After reading this portion of the text to the class, Ms. Freeman paused and asked the students to name some luminous objects in their immediate environment. The students offered several other examples, including objects and animals that were not in the classroom environment, and also discussed whether mirrors are luminous or nonluminous. They decided that mirrors are nonluminous and Ms. Freeman summarized the discussion, focusing on the luminous objects in their immediate environment, and then asked them to name nonluminous objects. The students had no trouble naming nonluminous objects, and were enthusiastic about this. As Ms. Freeman attempted to continue on to the next paragraph, David made an observation regarding what they had just read about luminous and nonluminous objects and how it related to their claims, still posted on the board.

David: Before we said that light isn't reflected by objects other than mirrors but the article says that light reflects off others so we can see them so we know that claim's wrong.

SF: And I think we'll get maybe some more information about this too as we move along. All right, next paragraph.

> When light travels from a luminous object to your eyes it has to travel through air. It may travel through other materials, too. Light travels through some materials differently than others.

At this point Ms. Freeman stopped and asked the children what they already knew in relation to that segment of text. The students remembered that one of their classmates, Ayaka, had attempted to shine light through various different types of material, including wood, glass, metal, and a paper milk carton, and that her claim was that some objects make darker shadows than others. Ms. Freeman encouraged them to look for more information regarding this claim as they read the next paragraph.

> Light travels straight through objects that are ***transparent***, or clear, such as glass windows or pop bottles. Because the light is traveling straight through the transparent object, we can see objects on the other side of the transparent object very clearly. Sometimes, only some light passes through objects. These objects, like plastic milk jugs, are called ***translucent***. If you look through a plastic milk jug, you won't see anything clearly on the other side, but you might notice that some light is shining through. Objects that don't allow any light to pass through are called ***opaque***. Books and walls are opaque. We can't see anything on the other sides of these objects.

Ms. Freeman stopped at the end of this paragraph and directed the students' attention back to the list of claims on the board:

SF: So, David, you said that there was one up here that this kind of proves as correct.

David:	Oh, Ayaka's. Because it said that some lets light come in differently, more light and less light. Less light would probably be a lighter shadow and more light would be a darker shadow.

After this, Ms. Freeman asked the students to name examples of transparent, translucent, and opaque objects in their immediate environment. The students did not have a problem naming transparent objects but the identification of translucent objects proved more elusive. The difference between transparent and translucent objects sparked a lot of discussion as students pointed out the different characteristics of objects on the room, especially the computer screens.

SF:	Translucent seems a bit harder. Evan?
Evan:	Um, the computer screen.
Student:	[*off camera*] That's what I was gonna say.
Jung Ho:	That's more transparent than translucent.
Nick:	Yeah, or else you'd see the light.
SF:	Guys. Jung Ho, why do you think that?
Jung Ho:	Well, 'cause then you wouldn't be able to see through the screen that easily. You can see yourself.
SF:	That's kind of a puzzle, but I think the screen itself must at least be transparent.
David:	Well, it can be, well, maybe some screen savers are, like that one for instance [*points across room*] is translucent and it has a picture that lets out some of the light not all of it. But when you move the mouse it gets really transparent.

The discussion about translucent objects continued for a few additional minutes, including more debate regarding the computer screen and whether it should be considered translucent or transparent. Then Ms. Freeman introduced the next section of the text. After reading the subtitle and before reading the next section, she again asked the students for predictions. The class then continued with this section.

> Light Bounces
>
> Did you use mirrors when investigating your claims about light? What happens when you hold a mirror facing a light box? You can see the path of the light bouncing off the mirror. The light from the box is hitting the mirror. Then it is bouncing off the mirror and hitting other things—other mirrors, targets, the desk or wall. Why does light bounce this way off mirrors? The surface of a mirror is very smooth. Light bounces off this smooth surface in an even, regular way. Most mirrors are made of glass with a thin coat of shiny silver on the back. What happens when light bouncing off you hits the mirrors? The light bounces off the mirror in the same pattern as it hit the mirror. You see yourself.

At this point Ms. Freeman paused and asked for a volunteer to summarize the paragraph. When the class continued reading, she explicitly drew the *students' attention to the claim that two students, Kevin and Ilya, had made following their firsthand investigation, and its relevance to the text.*

SF:	Did you try to get the light to travel using anything other than mirrors?
SF:	Kevin, did you try that? [*walks over and places hand on Kevin's shoulder*]
Kevin:	Yeah.
SF:	What do you think would happen if you tried to use white paper instead of a mirror?
SF:	What happened with white paper, according to Kevin and Ilya? Ilya, what happened?
Ilya:	Well, it would just go a little and then it stops.
SF:	It just seemed to stop? David?
David:	Well, it works sort of like a mirror but it's not quite as smooth I don't think because paper can be folded easily so it won't be as smooth as a mirror so it won't reflect as well. But mirrors, you can't bend a mirror or mess it up. It's very smooth. There's no way to do it. It's like rock.
SF:	All right, so we have two thoughts, Kyla and Ayaka. One thought is that light does not bounce off of anything but mirrors. And the other thought is that it does bounce off other things but because they're not smooth, as David said,
David:	They don't bounce as well.
SF:	They don't bounce as well. I want you to think about that, which one you kind of agree on at this point.

> Compared to a mirror, even the smoothest paper is very rough. Because the surface of the paper is rough, light that strikes it bounces in many directions. We say the light is scattered. It might be hard to see, but a faint light could be seen if you put your hand or a book in front of the paper. Some of the light bounces from the white paper to your hand or the book.

With this, Ms. Freeman stopped and asked the class, "Why don't we see the light as clearly bouncing off the white paper?" When students found this difficult to answer, she asked them what the article said about the surface of the paper. The answer to this question still eluded the class, so Ms. Freeman re-read the portion of the text related to this. After re-reading, the class voted on whether they thought light was reflected off of objects other than mirrors. Student opinion on this topic was split, and Ms. Freeman continued with the next paragraph.

> When light bounces it is said to be ***reflected.*** Light is reflected from one mirror to another mirror, or to a desk or a chair. Light is reflected from white paper or shiny things to your hand or a book. A page in the book may become bright enough for you to read by the reflected light. However, when light hits black paper, almost no light bounces from it. Instead of reflecting the light, most of the light energy is ***absorbed*** by the paper.

After this section, Ms. Freeman asked the class to remember Tim's claim from his firsthand investigation. The students recalled that Tim had predicted that black absorbed more light than white, and was therefore hotter, based on his experience playing soccer, while wearing dark and light colored jerseys. They also returned to their discussion of computer screens. Finally, Ms. Freeman concluded the lesson by reviewing each of the claims on the board and having the students discuss, based on what they had learned from the article, whether they agreed or disagreed with each claim.

Day 2 of Secondhand Investigations

Ms. Freeman began this lesson by reviewing the student's claims, recorded on the board. This discussion was similar to the one held at the end of the first day of the secondhand investigation, which was three days earlier.

SF: I want to review a little bit. Take a look up here. Turn your chairs so you can see if you're like Sarah and you're facing the front. I wrote the questions, the remaining questions we said we had from our secondhand and from our firsthand investigations, I wrote them pretty much how we said them last time. And I want to go through them real quickly. We're just going to read the last section of the article that we didn't get to before. OK, we said before, was there any information about black holes in the article?

Students: No.

SF: Was there any information on the speed of light?

Students: No.

SF: Hi, Katie. Yes, Nick?

Nick: I have something that shows that it's very, very, very fast. Whenever we turned the light box on, the light immediately shot out. There was no gap.

SF: Right. In any case, it's very fast. We just don't know exactly how fast from that, do we? Yeah, that's good. But the article really didn't say anything about it, or that it was the fastest thing in the solar system. [*points to claim on board*] So we still have no, no evidence about that. How about water splitting light into colors? [*points to next claim on board*] What did we say about that last time? Do we have any evidence in the article to show that that would happen? That water could do that? Nick?

Nick: No, but, um, I did when I put the plastic cup there, there was a little bit of, there was one blue strip of color.

SF: Yeah, we said we needed a little bit more information about that. Zoe?

Zoe:	Well, I just, about light is the fastest thing in the solar system?
SF:	Hm-mm?
Zoe:	Well, we know it's faster than sound because with lightning and thunder.
SF:	What happens?
Zoe:	Lightning gets here before the thunder.
SF:	Interesting. OK. Good observation. Do you know what she means by that?
Students:	Yeah.
SF:	Have you heard about that? OK, good.
Jung Ho:	I know why. Because light goes faster than sound.
SF:	That's what Zoe was saying. That's kind of a natural proof, isn't it? [*points to next claim on board*] Um, black absorbs, I put most here, we didn't have most on our claim but I think the article said most. Black absorbs most of the light and white reflects most of the light. And last time we proved that that was, or we found out from the article, that that was
Students:	True.
SF:	Um, anyone have anything more to say about that? About what we found out? [*no response from students*] OK, [*points to next claim*] Light is a source of energy.
Students:	no/yeah/no
SF:	The article said just a teeny bit about that, and I think it was in association, it was associated with this. [*points to previous claim, then to next claim*] How about light is reflected, oh, I changed this one, actually. We had up here last time light is not reflected by objects other than mirrors, and I changed it because we said no, that wasn't true. So I changed it to say, light is reflected by objects other than mirrors. And what did it say in the article about that? How do we know that that is true? That light is reflected by objects other than mirrors? Katie, what do you think?
Katie:	Well, because of, it said in here that [*looking at the article*] did you try light to travel with anything other than mirrors? And it bounces off. It's like,
SF:	OK, how does light bounce off of a mirror? [*no response from students*] OK, why don't you look at the second page, under light bounces. Right there in the middle. Can you turn to the second page? Kind of skim that paragraph. You see where it says how light bounces off a mirror? About two thirds of the way down?
Students:	uh-huh/yeah
SF:	Do you see that? Sarah, do you see that? About two thirds of the way down, that paragraph in the middle of the page? What does it say? What does it say, Katie?
Katie:	[*reading*] most mirrors are made of glass, even, re- [*starts again*] Most mirrors are made of glass with a thin coat of shiny silver on the back. What happens when light bouncing off you hits the mirrors? The light bounces off the mirror in the same pattern as it hit the mirror. You see yourself.
SF:	Actually even the sentence before that, or the two sentences before that, it says [*reading*] The surface of a mirror is very smooth. Light bounces off this smooth surface in an even, regular way. OK, how about other objects, then? If we said

that light bounces off of all things, all objects, then how is it different than bouncing off a mirror? They used white paper as an example. How is it different? Zoe, did you have an idea about that? [*Zoe shakes head no*] OK, David.

David: Um, it said in the article that even the smoothest paper is rough so it wouldn't bounce off as well because, um, paper is just not very, um, smooth.

SF: So the light would bounce off in all different

David: directions and scatter.

SF: Scatter.

At this point Ms. Freeman asked the class to vote again on whether they agreed that light bounces off everything. There were still several students who did not agree. One student, Julian, volunteered that he knew "...one thing that light does not bounce off of—air." Ms. Freeman added this statement to the class list of claims. The introduction of this topic sparked a debate among the students.

Nick: Ms. Freeman? [*Sally is writing Julian's claim on the board*]

SF: Yeah?

Nick: I know, I know, I think no for that one but I know why no. Because we can't see air. [We can't see air.]

Katie: [We can't prove it because we can not see air.]

Nick: That's because light doesn't reflect onto the air and then go to our eyes. Because it can't reflect off air.

Student: [*off camera*] Why not?

Katie: [We can't, we can't]

SF: Just a second. One at a time. Katie?

Katie: Well, we can't see air so it's like impossible to tell if that's true or not.

Nick: Well, it said, it said in the article the way you see things, or something like this, the way we see things is it reflects off that thing and goes to your eyes. But it can't reflect off air so it doesn't go to your eyes.

SF: Interesting. So that's sort of Nick's theory.

Katie: But we can't prove that.

At this point the discussion began to focus on whether we could test this claim, and whether we can in fact see air or not. Katie offered her dad's help in investigating this, and David B. made comments regarding smoke and steam, which he decided weren't pure air but air with water and "particles" in it. The class's discussion eventually sent them back to the article for information regarding whether light bounces off of or travels through air.

SF: OK, one more comment about that. Jung Ho?

Jung Ho: Well, it's just that I think light travels through air. It doesn't bounce off.

SF: Do you have any evidence in the article? Did it say anything about that in here?

Jung Ho: Well, not really but about Nick's claim.

SF: Did anyone see anything about that in here? About light traveling through air in the article?

Student: [*off camera*] No, but I've got something to prove.

SF:	Take a look at the first page. Just (?) with me. Look at the second paragraph. Do you see anything in there that talks about light traveling through air?
Students:	Yeah/yes/yeah
SF:	You see that? What is it? Ilya, can you read that sentence about that?
Ilya:	[*reading*] Luminous objects are objects that give off light.
SF:	Look at the top of that paragraph, the second paragraph.
Ilya:	Where?
SF:	The second paragraph. It says when.
Ilya:	Oh, OK. [*reading*] When light travels from a luminous object to your eyes it has to travel through air.
David B:	So it travels through air.

Notes

1. There were 18 teacher participants the first two years of this work (1996-98) and there were 14 active participants the third year of this work (1998-99).

2. The participants in this Community of Practice met biweekly (for four hours each meeting) during the two academic years from 1996 through 1998, and once monthly during 1999. In addition, they committed two weeks of full-days during the summers of 1996 and 1997 and one week during 1998.

3. The authors are grateful to Danielle Ford, who prepared the text used in Ms. Freeman's secondhand investigation.

4. It is, of course, possible for the instructional conversation to override the constraints of the text. For example, in one class, which was using the C-expository version of the refraction text, a child promptly placed a pencil in a bottle of water on his desk and proudly displayed his demonstration to his classmates, prompting conversation about this and related phenomena.

5. In preparation for reading these notebooks and using them in an interactive fashion, the class had been introduced to reciprocal teaching dialogues.

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About CIERA

The Center for the Improvement of Early Reading Achievement (CIERA) is the national center for research on early reading and represents a consortium of educators in five universities (University of Michigan, University of Virginia, and Michigan State University with University of Southern California and University of Minnesota), teacher educators, teachers, publishers of texts, tests, and technology, professional organizations, and schools and school districts across the United States. CIERA is supported under the Educational Research and Development Centers Program, PR/Award Number R305R70004, as administered by the Office of Educational Research and Improvement, U.S. Department of Education.

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